Driver sleepiness – comparisons between young and older men during a monotonous afternoon simulated drive

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ABSTRACT

Young men figure prominently in sleep-related road crashes. Non-driving studies show them to be particularly vulnerable to sleep loss, compared with older men. We assessed the effect of a normal night's sleep versus prior sleep restricted to 5h, in a counterbalanced design, on prolonged (2h) afternoon simulated driving in 20 younger (av. 23y) and 19 older (av. 67y) healthy men. Driving was monitored for sleepiness related lane deviations, EEGs were recorded continuously and subjective ratings of sleepiness taken every 200sec. Following normal sleep there were no differences between groups for any measure. After sleep restriction younger drivers showed significantly more sleepiness-related deviations and greater 4-11Hz EEG power, indicative of sleepiness. There was a near significant increase in subjective sleepiness. Correlations between the EEG and subjective measures were highly significant for both groups, indicating good self-insight into increasing sleepiness. We confirm the greater vulnerability of younger drivers to sleep loss under prolonged afternoon driving.

Key words: sleepiness, driving ability, age effects, road safety, driving simulator

Highlights

older vs young men under realistic, monotonous driving during afternoon dip, after 5h night sleep

Young drivers significantly more affected by sleepiness: more lane drifting and EEG sleepiness

Subjective sleepiness reached near significant greater increase in younger drivers

#Self -insight into increasing sleepiness was good for both groups

#Younger drivers have greater vulnerability to sleep restriction than older drivers.

INTRODUCTION

Fatal road crash statistics from around the world where the cause has been identified as the driver fallen asleep at the wheel, show a predominant involvement of young drivers (eg. USA - Langlois et al. 1985; Pack et al. 1995; Israel - Zomer & Lavie, 1990; UK - Horne & Reyner, 1995; Sweden - Åkerstedt & Kecklund, 2001). One reason may be that they are more vulnerable to sleep loss than older people, owing to a greater depth and intensity (more stage 4) of their sleep (cf. Adam et al. 2006; Klerman & Dijk, 2008; Dijk et al. 2010); thus sleep loss may be more profound in its effects. Whilst there have been several reports of young adults demonstrating greater vulnerability to sleep loss, such studies have commonly utilised simple performance indices, such as the psychomotor vigilance task (PVT) (Philip et al. 2004; Adam et al. 2006), whereas few have involved realistic driving situations.

Campagne et al. (2004) monitored three age groups (20-30y, 40-50y and 60-70y) driving for an average of 2h 49min, on a full-size simulator, and under monotonous conditions 'at night'. Run off the road driving errors were more frequent in younger participants than either of the two older groups. Lowden et al. (2009) compared young (18-24y) and older (55-64y) participants driving a full-size car simulator for 45min, between 02:30 and 04:00h. Findings clearly showed the younger group to be sleepier, as determined by EEG and subjective responses using the Karolinska Sleepiness Scale (KSS) (Åkerstedt & Gillberg, 1990). Although lane drifting was similar for both groups, the authors noted that this drive duration was fairly short. Sagaspe et al. (2007) utilised real road driving at night, with younger and older participants with the main aim to compare two countermeasures to sleepiness: a nap and caffeine (with a placebo). Under the placebo condition, 75% of the older participants were able to maintain normal driving performance compared with only 25% of the younger group.

These latter three driving studies were conducted at night. It should be noted that younger drivers are more likely than older drivers to drive very early morning, this is also the most likely time of day for younger drivers to have a sleep related collision (eg. Horne & Reyner,1995; Maycock, 1997; Flatley et al. 2004). On the other hand, the time of day when older (>50y) drivers are more likely to have sleep related collisions is early afternoon, ostensibly during the bi-circadian 'dip' (Horne & Reyner, 1995b). The aim of the present study is to compare the driving ability of both groups at this latter time of day which, hitherto, has not been investigated. This research may further address the issue whether the preponderance of young men being involved in early morning fall asleep crashes is simply through their being more likely to be on the road at this time of day, and/or they have a greater vulnerability to sleep loss.

Another aspect of this study is to compare the extent to which sleepy drivers are aware of their own sleepiness when driving. This has implications for driver responsibility, and has been a focus of our previous research as well as that of others. Close association between subjective and EEG measures of sleepiness in young drivers (eg. Horne & Baulk, 2003; Anund & Åkerstedt 2010) have been reported, to the extent that they are aware of increasing sleepiness. However, less is known about older drivers in this respect.

A recent driving study of ours, focussing on older men with obstructive sleep apnoea (Filtness et al 2011), included a control group of 20 age-matched healthy men. In the present report we compare the control group from Filtness et al (2011) with data for young drivers. Data for younger participants comprises that of 12 participants previously published in Horne et al. (2003) and 8 others from an unpublished study. In all cases identical protocols and the same real car simulator were used. All participants drove for 2h during the early afternoon 'dip', under conditions of a normal prior night's sleep vs sleep restricted to 5h (designed to worsen the dip). Measurements comprise lane drifting, EEG and subjective sleepiness.

METHOD

Participants

In the UK, men are responsible for the majority (90%) of sleep related collisions (Horne & Reyner 1995; Flatley et al 2004), and for this reason our participants were men. Two groups of healthy male drivers were recruited via local advert and were initially screened by postal questionnaire and phone. Initial screening excluded those with estimated BMIs >28, who drove for <3h per week or lived further than 40km of our research centre. Remaining potential participants were invited for an interview, which covered illnesses (especially heavy snoring and other signs of obstructive sleep apnoea), medications liable to affect sleep, habitual sleep characteristics, and to establish low coffee and alcohol consumption. BMIs were confirmed by measurements and all had BMIs in the range 20-27 kg/m^2. 20 older men (mean age 66.6y - 52–74y) and 20 younger men (mean age 22.7y - 20 – 26y were recruited. All were good sleepers, although the younger group had a (not significantly) longer average usual sleep duration (by actigraphy) of 503min compared with 468min for the older group. All were healthy, medication-free and scored <10 on the Epworth Sleepiness Scale (ESS – Johns et al. 1991). They were experienced drivers (having driven for over 2y, for more than 3h per week). A 30 min familiarisation drive in the simulator was completed by all participants prior to the experimental days. The procedures were fully explained and all signed consent forms. For participating, they received either a gift voucher or were paid the equivalent value on completion of the study. During both experimental phases, all participants were collected from and returned to their home by taxi. The investigation had full approval of the University's Ethical Committee.

Design and Procedure

Our standard experimental protocol undertaken by both groups, was as follows. Participants underwent a 2h simulator drive following two experimental sleep conditions : i) normal sleep ii) sleep restriction to 5h by delayed bed-time. Test days were completed in a counterbalanced design, with each condition 1-2 weeks apart. To ensure compliance with sleep instructions, participants wore wrist actimeters (Cambridge Neurotechnology, UK) for three nights prior to each experimental day, when they kept daily logs of estimated sleep onset, and morning wakening and rising times. No alcohol was consumed 36h prior to each test session, and nil caffeine after 18:00h the evening before. Participants refrained from eating after 10:00h on the morning of the drive. On arrival at the laboratory, at 13:00h, they were given a light lunch. Actimeters were downloaded to verify that they had complied with the previous night's sleep requirements. At 13:15h electrodes were applied and they went to the simulator at 13:50h, to be given 10 min to settle into the car. The 2h continuous drive began at 14:00h. A 2h drive was chosen because UK road safety organisations recommend that this should be the limit before a break from driving.

Apparatus

Car Simulator **:** This comprised an immobile car with a full-size, interactive, computer generated road projection of a dull monotonous dual carriageway; each having two lanes. The image was projected onto a 2.0m x 1.5m screen, located 2.3m from the car windscreen. The road had a hard shoulder and simulated auditory 'rumble strips' (incorporated into white lane markings) either side of the carriageway, with long straight sections followed by gradual bends. 'Crash barriers' were located either side, beyond the rumble strips. Slow moving vehicles were met occasionally, that require overtaking (to avoid collision). Participants drove in the left hand lane (unless overtaking), according to UK road rules, at a speed appropriate for the road and to enable full control of the vehicle. During the drive the investigator was in the room at all times, but there was no communication between investigator and participant once the drive had begun.

Driving incidents : Lane drifting is the most common manifestation of sleepy driving. When all four wheels came out of the driving lane (lane departure) this was identified as a driving 'incident'. Split-screen video footage of the road and driver's face (filmed by an unobtrusive infrared camera) were scrutinised and enabled the cause of the incident to be determined. Those caused by sleepiness (e.g. eye closure, eyes rolling upwards or vacant staring ahead) were logged as 'sleep-related'. As a further check for the latter, the EEG and electrooculogram (EOG) were examined respectively for alpha/theta intrusions and confirmation of any 'eye rolling'. Non-sleep related incidents (driver distraction, fidgeting or looking around) were excluded; therefore all results refer to sleep related incidents only.

Subjective Sleepiness : Every 200s during the drive, participants were verbally prompted by the computer system ('*sleep-check*') to report their subjective sleepiness on the 9-point KSS: 1=extremely alert, 2=very alert, 3=alert, 4=rather alert, 5=neither alert nor sleepy, 6=some signs of sleepiness, 7=sleepy, no effort to stay awake, 8=sleepy, some effort to stay awake, 9=very sleepy, great effort to keep awake, fighting sleep. The scale was located on the car's dashboard and permanently visible to the participant, this prompting and its response quickly became routine. Results are reported as absolute values at each ‘sleep check’.

EEG and EOG: Electrodes were attached for two channels of EEG, with inter-electrode distances maintained using the ‘10-20 EEG montage’ (main channel C_3-A_1, backup channel C_4-A_2). There were two EOG channels (electrodes 1cm lateral to and below left outer canthus and 1cm lateral to and above right outer canthus; both referred to the centre of the forehead). EEGs and EOGs were recorded using “Embla” (Flaga Medica Devices, Iceland) and spectrally analysed using “Somnologica” (Flaga) in 4s epochs. EEG low and high band-pass filtering at >20Hz and <4Hz removed slow eye movements and muscle artefact. In these circumstances, greater EEG power in the alpha (8-11Hz) and theta (4-7Hz) ranges reflect increased sleepiness. Power in the combined range (4-11 Hz) was averaged in one minute epochs. To accommodate for individual differences, and to allow comparisons between conditions, each individual’s power in these ranges was standardised, by taking the difference between each minute’s epoch and the individual’s mean value over the first 30min of baseline data, which was then divided by the standard deviation around the mean of that 30min of data (cf. Reyner & Horne 1997).

Statistical Analysis

Mixed model, repeated measures analysis of variance (ANOVA) were utilised, with one between-subject (groups) and two within subject factors: i) Condition – two levels: normal sleep and sleep restriction; ii) Duration of drive – four levels: 0-30 min, 30-60min, 60-90min and 90-120min. Huynh-Feldt (ε) adjustments were used if the assumption of sphericity was not met. Where appropriate square root transformations corrected for skewed driving incident raw data. For all measures, data was collapsed into 30 minute epochs for statistical analysis

RESULTS

Driving Incidents – Figure 1.

There was a significant main effect for sleep condition on the number of driving incidents, with both groups having more incidents following sleep restriction [$F(1,38) = 27.67$, $p = 0.000$, $\varepsilon = 1$]. A significant condition by group interaction showed the younger participants were more impaired by sleep restriction [$F(1,38) = 9.92$, $p = 0.003$, $\varepsilon = 1$]. There was also a significant time effect, with number of incidents increasing for both groups with time on task [$F(2.6, 99.0) = 4.8$, $p = 0.005$, $\varepsilon = 0.87$]. Although Figure 1 indicates a greater number of driving incidents by younger participants between the first and second 30 minutes of the drive, there was no significant group by time interaction, here.

KSS - Figure 2.

The effect of sleep restriction was significant, [F (1,38) = 46.55, p = 0.000, ε = 1]. There was a near-significant trend for a sleep condition by group interaction [F (1,38) = 3.41, p = 0.073, ε = 1], with the younger group tending to report greater sleepiness after sleep restriction than the older participants. There was a significant effect of time [F(2.06, 78.09) = 39.87, p = 0.000, ε = 0.69] with sleepiness worsening with drive duration for both groups, but no significant group by time interaction.

EEG - Figure 3.

There was no overall significant effect of sleep condition on standardised EEG activity (alpha and theta), but there was a significant sleep condition by group interaction [F (1,36) = 5.03, p = 0.031, ε = 1], whereby the younger participants showed more EEG determined sleepiness following sleep restriction than the older participants. The effect of time was also significant [F(1.84, 66.29) = 18.71, p = 0.000, ε = 0.61] with sleepiness increasing throughout the drive for both groups, but with no other significant interactions.

Correlations between KSS and EEG – Figures 4a and b.

For both groups under sleep restriction conditions, the mean EEG data were collapsed into 200 sec epochs, smoothed by a three point running average and then compared with KSS group means per 200sec. For both groups, the correlations were highly significant, as can be seen, particularly for the older group [Older - r = 0.90 ; p<0.000 df=35; Young - r = 0.72 ; p<0.001 df=35]. Also shown in Figures 4a and b, are 5^{th} order polynomial fits of these data, illustrating the closeness of the two variables.

DISCUSSION

Following sleep restriction, and compared with the younger group, older participants had significantly less sleep related driving incidents, lower EEG power in the 'sleepy' range, and a near- significant lower level of subjective sleepiness. These effects of sleepiness also took longer to develop in the older group. These findings, which point to the older drivers being less vulnerable to sleep loss related driving impairments, are generally in agreement with previous night time driving studies (Campagne et al. 2004; Reyner & Horne 1997; Lowden et al. 2009). An important outcome for both our groups was that they had good insight into their increasing sleepiness following sleep restriction, with close associations between subjective and EEG measures of sleepiness.

Given that ours was an early afternoon drive, and that road traffic accident data (e.g. Flatley et al. 2004) indicate relatively more older drivers having sleep related collisions at this time of day, compared with younger drivers, it might have been expected that our older drivers would also have had more incidents, however, the reverse was found. One explanation may be that rather than older drivers being more liable to fall asleep at the wheel during the early afternoon than are younger drivers, proportionately there may just be more older drivers on our roads at this time of day, in the same manner that there appears to be more younger drivers on the roads in the early morning. Unfortunately, there are no UK statistics on road usage by age and time of day.

Important to road safety is a driver's ability to recognise when they are sleepy, so that they can act on this knowledge and stop driving before an incident occurs. We found that both our groups had good insight into their increasing sleepiness following sleep restriction, with there being close associations between subjective and EEG measures of sleepiness. We have reported this previously in younger participants and now are able to extend this finding to older participants, who seem somewhat even better at this, given the higher correlation between these two indices for the older group.

This being a simulator-based study, it could be argued that the findings are of limited comparability with real driving conditions. But whilst it is ethically difficult to conduct such studies on real roads, it is likely that without the awareness of danger (quite apparent under real conditions), simulator studies are liable to reflect greater and more rapid effects of sleepiness. Nevertheless, ours was a full size, and realistic car simulator, and comparisons between real driving and laboratory studies, even with the latter utilising simpler simulators than ours, have shown that the two methods are comparable (Philip et al 2005), albeit somewhat exaggerated in the laboratory.

The duration of our drive was chosen to reflect the recommendations by various UK road authorities about the length of driving before a break. As both our groups were having sleep related incidents throughout the drive, this may suggest that under monotonous afternoon driving, and after a restricted night's sleep, such breaks ought to be more frequent.

Our younger drivers had slightly longer habitual (av. 35min) sleep, and as both groups were restricted to 5h sleep during the experimental condition, it is possible that part of their greater driving impairment was due to a greater sleep restriction. Whilst this may have been a limitation of the study, it does enable comparisons between age groups experiencing the same absolute amount of sleep restriction. However, the greater vulnerability of the younger group to this sleep restriction potentially puts them at a greater driving risk under these circumstances, and may help further explain the relatively high proportion of young men being responsible for serious sleep related road collisions.

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FIGURE LEGENDS

Figure 1

Group mean driving incidents (s.e. bars) per 30 min of drive for both groups and sleep conditions. Sleep loss significantly worsened driving in the younger group.

Figure 2

Subjective sleepiness (KSS) – group means per 200sec for groups and conditions. The greater effect of the sleep loss on the younger group was near significant.

Figure 3

EEG alpha+theta power (indicative of increasing sleepiness), per minute for both groups and sleep conditions. Data have been smoothed by a 3-point running average. Sleep loss led to a significant increase in alpha and theta power in the younger group.

Figure 4a and b

Smoothed EEG alpha+theta power with 5th order polynomial fits, plotted with KSS for older (top graph) and younger drivers (bottom). There was a highly significant correlation between both variables.

Figure 1

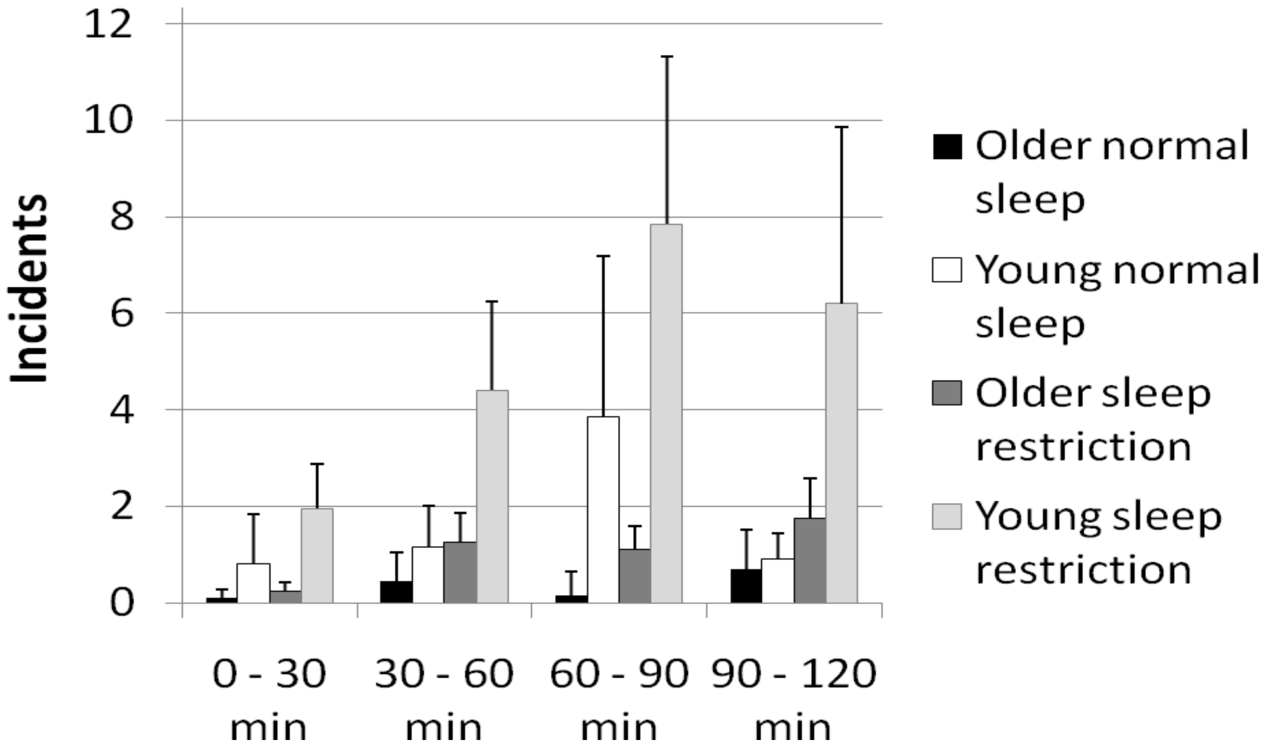

12
10
8
6
4
2
0
Incidents
0 - 30 min
30 - 60 min
60 - 90 min
90 - 120 min
Older normal sleep
Young normal sleep
Older sleep restriction
Young sleep restriction

Figure 2

Figure 3

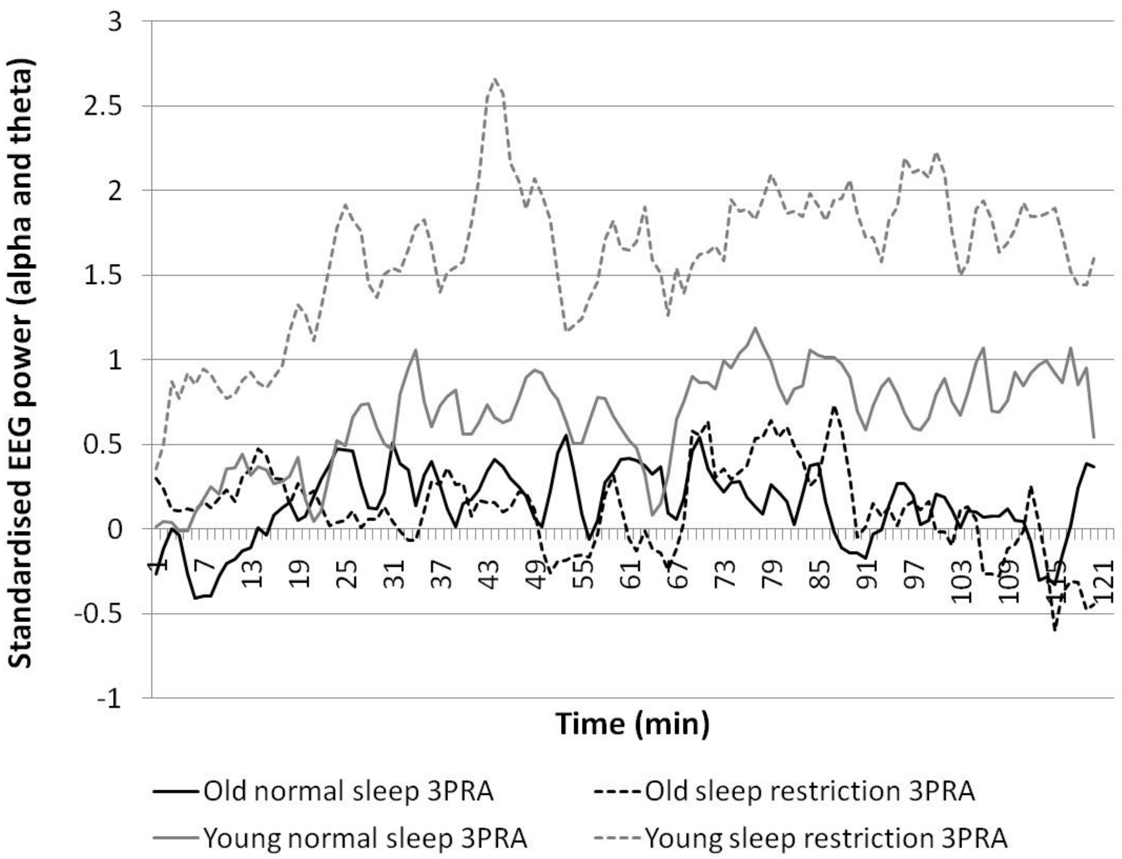
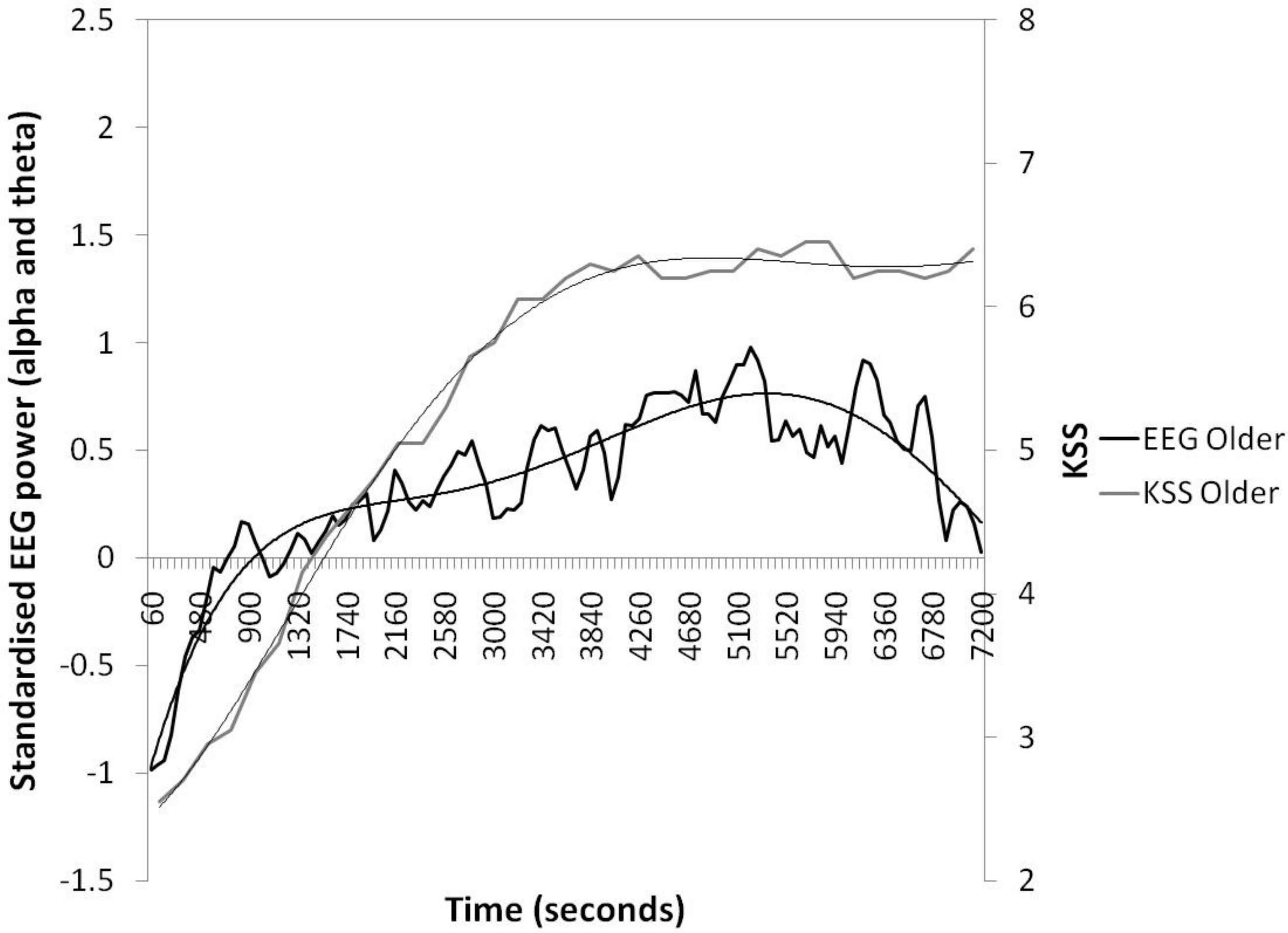
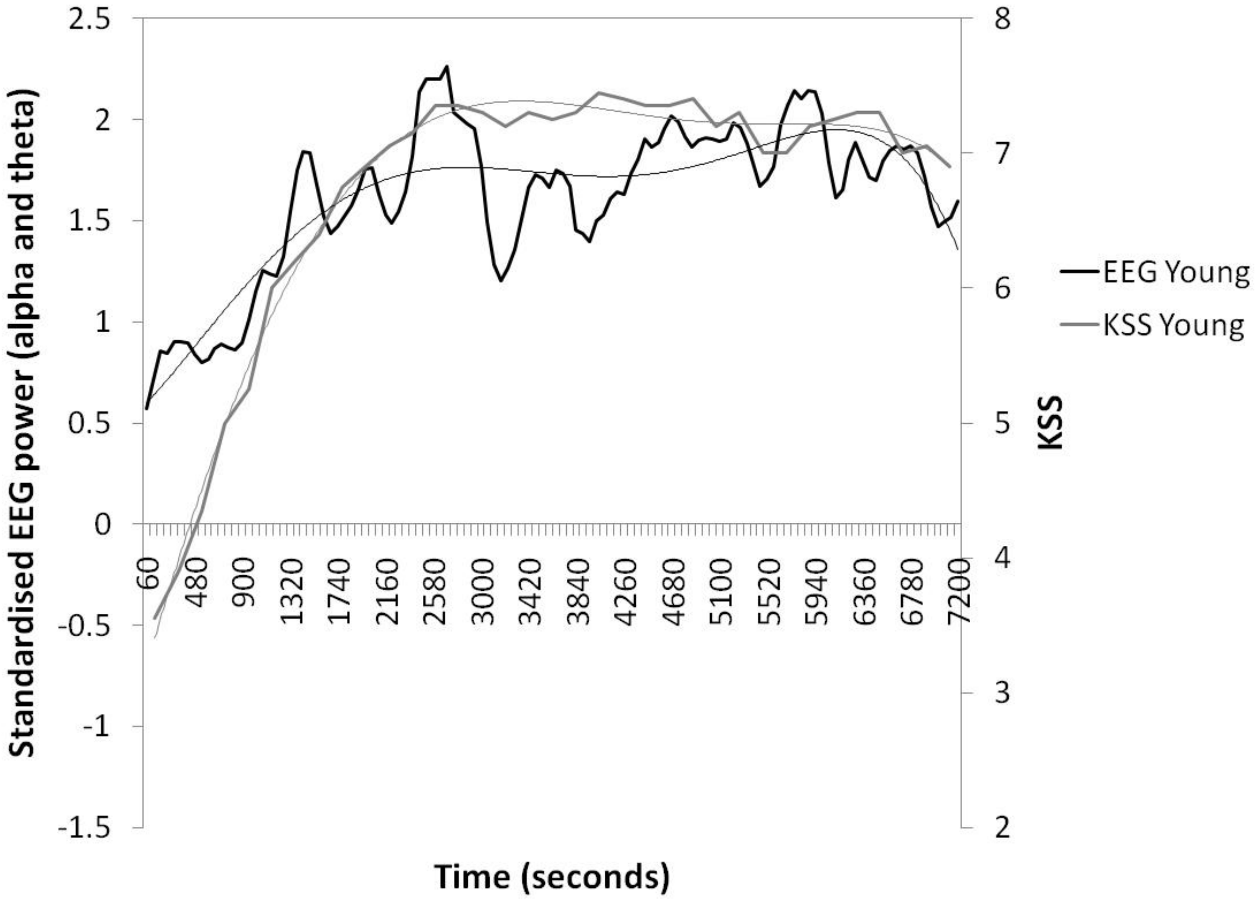


Figure 4a



Standardised EEG power (alpha and theta)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
8
7
6
5
4
3
2
KSS
60
480
900
1320
1740
2160
2580
3000
3420
3840
4260
4680
5100
5520
5940
6360
6780
7200
Time (seconds)
EEG Older
KSS Older

Figure 4b


Standardised EEG power (alpha and theta)
KSS
Time (seconds)
EEG Young
KSS Young
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
8
7
6
5
4
3
2
60
480
900
1320
1740
2160
2580
3000
3420
3840
4260
4680
5100
5520
5940
6360
6780
7200